Preventive oral hygiene and ventilator-associated pneumonia in paediatric intensive care unit



F. S. Ludovichetti, A. Zuccon, P. Positello, N. Zerman*, A. Gracco, E. Stellini, S. Mazzoleni

Department of Neurosciences – Dentistry Section, Università degli Studi di Padova, Padova, Italy
**Department of Surgery, Dentistry, Paediatrics and Gynaecology, University of Verona, Verona, Italy*

e-mail: francesco.ludovichetti@unipd.it

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Abstract

Aim Data indicate a tendency towards an increased incidence through the last decades of various forms of pneumonia. Among these, nosocomial pneumonia in patients who have been on mechanical ventilation support (increased after the Covid-19 pandemic) is a condition that must be addressed as soon as possible to avoid complications. Current literature lacks an in-depth analysis of the potential correlation between ventilator-associated pneumonia and poor oral hygiene, especially in children. The aim of this literature review is to investigate if improving oral hygiene could affect the onset of nosocomial pneumonia in children.

Materials and methods A search was performed in Pubmed, Medline, and Scopus for the keywords: oral care, children, neonates, ventilator-associated pneumonia, combined with 'AND' or 'OR' Boolean Operators.

Results The search yielded 236 potentially eligible articles; after exclusion for duplicates and title, and after the abstract and full text review, 12 articles were selected: 2 literature reviews, 1 pilot study, 4 observational studies, 1 survey and 4 randomised controlled trials.

Conclusions The relevant papers retrieved in the scientific literature emphasised the importante of good oral care bundles to mitigate the bacteria proliferation in the bloodstream, and to prevent the development of ventilator-associated pneumonia.

KEYWORDS Oral hygiene; Ventilator-Associated Pneumonia; Paediatric intensive care unit; Paediatric dentistry.

Introduction

According to the Centers for Disease Control and Prevention (CDC), ventilator-associated pneumonia (VAP) is a nosocomial pneumonia in a patient who has been on mechanical ventilation support for at least 48 hours [Horan et al., 2008].

With respect to the youngest population, paediatric VAP (increased after the Covid-19 pandemic) [Ludovichetti et al., 2020] is extremely relevant, and it can be referred to as early-onset or late-onset. In the first case, it manifests within 120 hours and it is caused by fully sensitive organisms [Richards et al., 1999]. When paediatric VAP takes place in more than 120 hours, multi-resistant organisms are involved [Pieracci et al., 2007], discarding the chance of operating with several types of antibiotics.

While most of the studies concerning VAP are related to adult patients [Benitez et al., 2005], investigations towards preventive bundles for children [Safdar et al., 2005; Folgia et al. 2007] have fundamental importance, as they are created to cluster together specific intervention techniques for infection control [Brierley et al., 2012; Smulders et al., 2013]. To keep VAP under control, four strategies are typically used [Coffin et al., 2008; Muscedere et al., 2008]: 1) general measures; 2) interventions to avoid aspiration of oropharyngeal secretions; 3) attention to minimise oropharyngeal colonisation; 4) reduction of device contaminations [Bigham et al., 2009; Sinuff et al., 2013; Viana et al., 2013]. Immobility, lack of laryngeal reflex and swallowing, presence of nose/orogastric tube and medications (such as antibiotics, inotropes, diuretics, anticonvulsants and sedatives) may lead to fast and severe development of VAP in paediatric patients [Hunter et al., 2012; American Thoracic Society, 2005].

Inside Paediatric Intensive Care Units (PICUs), VAP is the second most common nosocomial complication, peculiarly affecting the 2-12 months' age group [Elward et al., 2002], and it can lead to serious consequences, such as longer periods of time on intubation and higher mortality risk [Srinivasan et al., 2009; Tang et al., 2009]. Through this path of hospitalisation, the oral cavity is significantly colonised by pathogens. Initially, Gram positive organisms, such as Staphylococcus Aureus, infect the oral fissure. At a later stage, Gram negative ones, like Pseudomonas Aeruginosa and Haemophilus Influenzae, known to be more virulent and difficult to eradicate, start to proliferate [Babcock et al., 2003; Grap et al., 2004]. Saliva plays a main role in maintaining the oral mucosa moist and protecting teeth, by rebalancing the acid pH thus preventing hydroxyapatite from dissolving. Unfortunately, intubation demands the oral cavity to stay open for long periods of time, thus causing xerostomia and compromising oral health and teeth integrity. Plaque begins to accumulate and, if not treated properly, it evolves into tartar, which determines major bone structures and mucous membranes deterioration. Moreover, newly erupted teeth are extremely vulnerable to decay [Wong

et al., 1999], since their mineralisation process is not completed yet. Therefore, prevention is typically enforced through three main methods: teeth brushing, pharmacological treatment and the combination of the two methods [Munro et al., 2004].

As oral hygiene appears to have a fundamental role in preventing VAP in children, this review is aimed at analysing the current literature with respect to the potential relationship between paediatric VAP and poor oral hygiene, and at investigating if improving oral hygiene could affectthe onset of nosocomial pneumonia in children in PICUs.

Materials and methods

The currently available literature on the efficacy of oral hygiene in paediatric VAP was collected and analysed.

This literature review was performed according to the following research question: Can preventive oral hygiene procedures minimise bacterial proliferation and the risk of developing VAP in PICUs?

A comprehensive literature search was completed by the first author of the work using the keywords: oral care, children, neonates, ventilator-associated pneumonia, using the basic Boolean operator 'AND' and 'OR' to combine these words and limiting the search to the English language. Searches were completed in Pubmed, Medline and Scopus databases. All the authors of the present work performed independent title and abstract review to include potentially eligible articles. Then, independent full article reviews were performed on the articles included from the initial search to evaluate their relevance to the research question. Only studies considering children hospitalised in PICUs were considered in the present literature review.

Results

The search yielded 236 potentially eligible articles; after exclusion for duplicates and title, and after the abstract review, 21 articles were selected. Full text reading reduced the number of relevant articles to 12. Among them, 2 were reviews, 1 a pilot study, 4 observational studies, 1 survey and 4 Randomized Controlled Trials (RCTs). They are all summarised in Table 1.

Discussion

Correlation between oral health and pneumonia

Periodontal disease and poor oral health have a key role in contributing to the development of various systemic conditions. The correlation between periodontal diseases and oral health is still being attentively considered and examined by 'periodontal medicine' experts, who have already suggested consequences of a poor oral health and periodontal diseases in cardiovascular disorders, diabetes, infertility, premature birth, neurological complications, cancer, rheumatoid arthritis, osteoporosis, respiratory disease and many more.

It is now clearly stated that respiratory pathogens of patients with hospital-acquired pneumonia are comparable with those present in their oral cavity [Li et al., 2021]. Indeed, accurate oral care is crucial to prevent bacteria from dissemination in the host and increase the risk of developing serious health complications.

The pathogenesis of pneumonia caused by oral bacteria is the result of multiple factors. Firstly, the aspiration of oral pathogens is a carrier of severe lung infection. Moreover, periodontal disease-associated enzymes in saliva may promote the proliferation and adhesion of microorganisms to mucosal surfaces. Furthermore, it has to be remembered that in the gingival sulcus there are several types of immune cells. Nevertheless, once the pathogens begin to alter the microbiota, the immune system, while aiming at fighting the infection, ends up deteriorating the tissues, leading to an overproduction of cytokines. Lastly, cytokines released by the periodontal tissues modify the respiratory epithelium, thus accelerating the development of an infection. The final consequence of the microorganisms colonisation on teeth surfaces and tissues is dental plaque: 1 mm^3 of plaque is composed of more than 108 bacteria belonging to more than 300 species [Fourrier et al., 1998].

The ICU environment facilitates plaque and tartar buildup on the teeth, thus resulting in dental decay, caries onset and periodontal diseases. In this perspective, the main concern of PICUs is related to the risk of developing VAP, which is much higher in children than in adult patients. This can be mainly related to the use of uncuffed endotracheal tubes, nasal endotracheal tubes, open circuit suction, saline lavage during suctioning and the presence of primary teeth [Johnstone et al., 2010]. Furthermore, patients in developmental age easily suffer from xerostomia, caused by the frequent intake of medications and infusions [McNeill, 2000]. This condition contributes to the rapid deterioration of the oral cavity conditions and facilitates the proliferation and accumulation of bacteria in the whole body.

Professional oral hygiene, whether mechanical, pharmacological or combined, has to be assured in order to maintain a balanced microbiota and health status.

Mechanical oral care intervention

As a matter of fact, children and newborns, whose teeth have not yet erupted, being on mechanical ventilation need special attention. This need can be underestimated by caregivers, and hard to handle for parents and healthcare workers with limited oral health knowledge, often believing that hygiene procedures should be carried out only after tooth eruption. Newborns have a strong tendency to develop oral lesions and infections, due to their thin mucosa, containing a high number of blood vessels and underdeveloped salivary glands, which do not provide a sufficient amount of saliva [Li et al., 2021]. Therefore, also in newborns, gingival health must be preserved through specific treatments, outlined by the New Zealand Dental Association Guidelines released in 2006. Thus, a small, soft toothbrush, or a gauze swab soaked in clean water or saline solution should be employed to wipe the newborn's gums.

Researchers recommend the use of small and soft toothbrushes In dentate children on ventilation [Munro et al., 2004]. In fact, toothbrushes provide a high standard of care in mechanically de-plaquing teeth, thus reducing the risks of developing VAP [Turton, 2008].

Pharmacological oral care intervention

As oral hygiene may not be enough to protect children from severe infections, and may be performed incorrectly, pharmacological interventions tend to be required.

In the ICU environment, toothpaste is not always an option, since it may be not properly rinsed, and the risk of ingestion is high.

Reference	Country	Aims/purpose	Methodology	Key findings and results
Turton P. (2008)	United Kingdom	To identify relevant literature about paediatric VAP and use this in association with research carried out in the adult environment to establish VAP implications and possible management strategies.	Review	Discrepancies and inconsistencies exist about identification and treatment of VAP. This reflects in a dearth of literature on this topic, and in the lack of national standards for the management of VAP.
Johnstone L. et al. (2010)	New Zealand	To improve standards of oral care for children in PICUs.	Survey	More research in the paediatric critical care setting is needed to foster the development of evidence-based guidelines for oral hygiene.
Brierley J. et al.(2012)	United Kingdom	To assess the relationship between the settlement of a novel care bundle and the reduction of paediatric VAP.	Observational study	Successful reduction of paediatric VAP after the implementation of the prevention bundle.
Kusahara D.M. et al. (2012)	Brazil	To test the efficacy of oral care with 0.12% chlorhexidine in decreasing VAP in critically ill children.	RCT	The use of 0.12% chlorhexidine did not significantly modify the VAP incidence in a group of mechanically ventilated children.
Kusahara D.M. et al. (2012)	Brazil	To analyze the effect of 0.12% chlorhexidine digluconate on the colonization of oropharyngeal and tracheal secretions by Gram-negative pathogens in mechanically ventilated children.	RCT	The use of chlorhexidine did not significantly influence the colonization of oropharyngeal and tracheal secretions by Gram-negative pathogens of the considered sample.
Sebastian M.R. et al. (2012)	India	To study the efficacy of oral mucosal decontamination with chlorhexidine gel to prevent VAP in 3-month-15-year old children.	RCT	Application of 1% chlorhexidine gel on oral mucosa did not prevent the development of VAP in children aged 3 months - 15 years.
Stefanescu B.M. et al. (2013)	USA	To evaluate the feasibility of a randomized trial of timed oral care with Biotene OralBalanceR gel and estimate the required sample size.	Pilot study	The results supported the feasibility of a randomized trial of timed oral care with Biotene OralBalanceR gel for prevention of VAP in mechanically ventilated neonates.
De Cristofano A. et al. (2016)	Argentina	To apply a bundle for VAP prevention in PICU, aiming to decrease VAP rate by 25% every 6 months over a period of 2 years.	Observational study	The implementation of the bundle was associated with a reduction in VAP rate of 25% every 6 months and a nil rate in the last semester.
Hua F. et al. (2017)	China	To assess the effects of oral hygiene care on incidence of VAP in critically ill patients receiving mechanical ventilation in ICUs.	Review	Chlorhexidine reduces the risk of VAP from 24% to about 18%, but there is no clear evidence of its effects on the numbers of died patients in ICU, or on the hospitalization time.
McBeth C.L. et al. (2018)	USA	To reduce the VAP rate in PICU/cardiac ICU to fewer than 2 events per 1000 ventilator days within 2 years and to sustain a rate near 0 for the following 5 years.	Observational study	Within 2 years, the annual VAP rate fell from 7.86 to 1.16 events per 1000 ventilator days. There were no VAP events during a 10-quarter period in 2012 through 2014.
Behzadi F. et al.(2019)	Iran	To determine the effectiveness of the nurse education program on the performance of nurses in providing oral care for mechanically ventilated children.	Observational study	The performance scores of nurses improved significantly in four weeks after the education program intervention.
Li D.F. et al. (2021)	China	To investigate the effect of oral care via the combined use of colostrum and sodium bicarbonate on the prevention of neonatal VAP.	RCT	The incidence rates of VAP and oral infection after sputum culture of the experimental group were significantly lower than in control groups ($p < 0.05$).

TABLE 1 Articles inclused in the present review, with their main features and purposes.

A very recent study, carried out in 2021, analyse the efficacy of the combination of colostrum and sodium bicarbonate for the prevention of VAP in newborns [Li et al., 2021]. Bicarbonate is able to maintain the oral environment pH slightly alkaline, and to inhibit the growth of acidophilic organisms, while the colostrum has high concentrations of secretory immunoglobulin A (sIgA), anti-inflammatory cytokines, growth factors, lactoferrin and antioxidants, their combination provides a significant decrease in the VAP incidence compared to the use of those substances separately. More in detail, 120 patients in PICUs were divided into three groups: 1) combination of colostrum and bicarbonate; 2) only bicarbonate; 3) only colostrum. The number of patients who developed VAP in each group was respectively: 2 (6.67%), 8 (26.67%) and 6 (20.00%), confirming the combined effects of bicarbonate and colostrum in preventing VAP in newborns [Li et al., 2021]. Also the use of an LP3 enzyme protein system gel (Biotene OralBalance) was investigated by an American pilot study in preterm ventilated infants with the aim of reducing the frequency of VAP [Stefanescu et al., 2013]. The study was performed on 40 subjects who were divided into two groups: half of them were treated with the gel, and the other half was used as control group, using only sterile water. After two years of study (2010–2012), no significant evidence of efficacy of the gel was observed, founding just a slight trend towards fewer episodes of VAP [Stefanescu et al., 2013].

Current debates revolve around the efficacy and critical issues related to the use of chlorhexidine to prevent VAP. A

consensus statement has yet to be reached, given the variety of patients and their oral and systemic conditions included in each study on this topic.

An attempt toward the definition of the efficacy of chlorhexidine was made in 2012 by Kusahara and co-workers [Kusahara et al., 2012], aiming to asses if 0.12% chlorhexidine could decrease VAP in critically ill children. On that account, 96 children were divided into two groups, one treated with chlorhexidine, and one with placebo as control. Oral care was assured twice a day by the use of a toothbrush and an antiseptic gel. No significant differences between the two groups in terms of colonisation by Gram-positive and Gram-negative bacteria were detected, as well as for hospital mortality rates, ventilator period and days in PICU. However, one interesting feature was highlighted: in those patients with no pathogenic flora on Day 0, chlorhexidine was found to be protective against VAP [Kusahara et al., 2012].

In another work, from 2007 to 2009, 86 patients were hospitalised in the PICU of the Department of Paediatrics at the Indian institute of Medical Sciences, and they were treated either with 1% chlorhexidine gel or placebo. No significant differences in VAP progression were observed. Specifically, 12 patients out of 41 in the chlorhexidine group, and 14 out of 45 in the placebo group developed VAP [Sebastian et al., 2012].

A review study published in 2017 reported that chlorhexidine (either mouthwash or gel) was able to reduce the risk of developing VAP from 24% to about 18%, even if no effects were noticed concerning mortality, time of ICU stay and duration of mechanical ventilation [Hua et al., 2016].

Altogether, chlorhexidine seems to have a more powerful effect on Gram-positive pathogens rather than on Gram-negative ones. This result can partially explain the lack of efficacy of this antiseptic against oropharyngeal and tracheal colonisation by Gram-negative pathogens, typical of VAP patients.

Furthermore, statistics highlighted the notable influence of the child's age on the presence of Gram-negative bacteria in oropharyngeal secretions: younger kids seemed in fact more susceptible to these pathogens [Kusahara et al., 2012].

Limitations of the present work

This review work considered the relevant issues related to the onset of VAP in children, aiming at identifying potential correlation between VAP and oral hygiene, thus addressing a topic often neglected by interventist clinicians and researchers, despite its fundamental importance.

The main limitation of the current study is related to the limited number of relevant research works retrieved in the scientific literature, that does not allow to draw definitive conclusions. Furthermore, the studies applied different methods on different subject groups, thus not allowing for a statistical comparison of the results.

Conclusion

In conclusion, the analysed studies emphasise the importance of oral care bundles to mitigate the bacteria proliferation in the bloodstream.

Most of the results indicated an interesting efficacy of mechanical and pharmacological interventions in decreasing or preventing the onset of VAP. Still, no clear evidence was found about the use of chlorhexidine; in this perspective, further investigations are required. Nonetheless, paediatric health care surely requires greater recognition when linked to dental issues, that often happens to be underestimated.

A close collaboration among nurses, doctors and dental professionals specialised in paediatric dentistry would probably decrease the exacerbation of their respiratory condition.

Statements and declarations

Authors state that they do not have any financial or non-financial interest directly or indirectly related to the present work.

Authors'contribution:

LSS: Design of the work; Data analysis and interpretation; critical revision of the article; final approval of the version to be published. GA and ZN: Drafting the article; critical revision of the article; final approval of the version to be published.

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